A PROSPECTIVE ANALYSIS OF BONY UNION AND FUNCTIONAL OUTCOME OF TRANSOSSEOUS OSTEOSYNTHESIS WITH ILIZAROV EXTERNAL RING FIXATION SYSTEM IN INFECTED NONUNION FRACTURE TIBIA

Dissertation submitted to

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for the award of the degree of

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ORTHOPAEDIC SURGERY

GOVERNMENT MOHAN KUMARAMANGALAM

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CERTIFICATE

This is to certify that **Dr. S.AMARNATH**, Postgraduate student (2009-2012) in the Department of Orthopaedics, Government Mohan Kumaramangalam Medical College, Salem, has done this dissertation **"A Prospective analysis of bony union and functional outcome of transosseous osteosynthesis with Ilizarov external ring fixation system in infected nonunion fracture Tibia"** in partial fulfillment of the regulation laid down by the Tamilnadu Dr. M.G.R Medical University, Chennai for MS Branch II (Orthopaedic surgery) degree examination to be held during April 2012.

Date: **Unit Chief**

Date: **Head of the Department**
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DECLARATION

I, **Dr. S.AMARNATH**, solemnly declare that this dissertation titled **"A Prospective analysis of bony union and functional outcome of transosseous osteosynthesis with Ilizarov external ring fixation system in infected nonunion fracture Tibia"** is a bonafide work done by me at Govt. Mohan Kumaramangalam Medical College Hospital, Salem between the period 2009-2012, under the guidance of my unit Chief **Prof.Dr.M.ANTONY VIMALRAJ M.S(Ortho).** This dissertation is submitted to Tamilnadu Dr.M.G.R Medical University, towards partial fulfillment of regulation for the award of M.S.Degree (Branch – II) in Orthopaedic Surgery.

Place : Salem

Date : **(Dr. S. AMARNATH)**

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ABSTRACT

Infected nonunion has been defined as “a state of failure of union and persistence of infection at the fracture site for 6 to 8 months”. Long standing infected non-union and gap non-union is difficult to treat and is a challenging problem for the orthopaedicians. The problems associated with infected nonunion are multiple discharging sinuses, soft tissue loss, chronic osteomyelitis, osteopenia, joint stiffness, contractures, complex deformities, limb-length discrepancy, and multidrug resistance of the micro-organisms.

A well-aligned, painless, healed and functional limb is the goal of treatment which is achieved by adequate and complete debridement, stable fracture stabilization, good soft tissue coverage and reconstruction of the bony defect.

We have done a prospective analysis of Transosseous osteosynthesis with Ilizarov external ring fixation system in cases of infected nonunion fractue Tibia with a sample size of 20 patients, either with or without active infection.

Of the analysed 20 patients, the mean follow-up of the patients was 7 months. The longest follow-up being 17 months and the shortest being 5 months.

The average time period for achievement for solid bone in our study is about 160 days. This method helped us in the control of infection, to achieve solid bone union and to attain a good functional outcome. The patients were analysed for bony union and functional outcome based on the ASAMI scoring system.

In our study “A PROSPECTIVE ANALYSIS OF BONY UNION AND FUNCTIONAL OUTCOME OF TRANSOSSEOUS OSTEOSYNTHESIS WITH ILIZAROV EXTERNAL RING FIXATION

SYSTEM IN INFECTED NONUNION FRACTURE TIBIA” , 10 patients had excellent and 6 had good bony union. 12 patients had excellent and 4 patients had a good functional outcome according to the ASAMI scoring system.

The Ilizarov ring fixator gives an option of compression, distraction and bone transport, and is effective in the treatment of infected nonunion fracture Tibia, where other types of treatment have failed . Ilizarov method is a minimally invasive, cheaper, versatile, cosmetic and 360 degree stable method. Early weight bearing is the key factor that distinguishes it from other conventional methods of fixation infected non-union Tibia. It promotes early functional recovery, eliminating fracture disease. Weight bearing and the functioning of the joints while on the treatment is an advantage of this technique.

In the present scenario, the best available solution for management of infected nonunion of fracture Tibia associated with bone defects, limb length discrepancies, deformities is the Ilizarov ring fixation system. Transosseous osteosynthesis with Ilizarov ring fixation system is the safest, simplest, most economical and effective method for the management of infected nonunion fracture Tibia.

KEYWORDS

Infected nonunion of long bones, Fracture shaft of Tibia, Transosseous osteosynthesis, Ilizarov external ring fixation system, Distraction osteogenesis, Corticotomy and Bone transport, ASAMI scoring system

CONTENTS

INTRODUCTION

Infected nonunion has been defined as "a state of failure of union and persistence of infection at the fracture site for 6 to 8 months"[1]. The problems associated with infected nonunion are multiple discharging sinuses, soft tissue loss, chronic osteomyelitis, osteopenia, joint stiffness, contractures, complex deformities, limb-length discrepancy, and multidrug resistance of the micro-organisms. Long standing infected non-union and gap non-union is difficult to treat and is a challenging problem for the orthopaedicians. It may lead to uncontrolled infection, residual deformity, joint stiffness and contracture, at worst - an useless limb. Filling the bony defect and control of infection are the crucial factors related to management and prognosis. Gaps of size larger than 4 cm cannot be effectively bridged by corticocancellous bone grafting[2].

A well-aligned, painless, healed and functional limb is the goal of treatment[3] which is achieved by adequate and complete debridement, stable fracture stabilization, good soft tissue coverage and reconstruction of the bony defect[4,5].

Corticocancellous bone graft[4,6], vascularized bone graft[7], non-vascularized fibula[8], distraction osteogenesis[2,9,10], posterolateral bone graft[11] and fibula pro-tibia (transfer of the ipsilateral fibula)[3,12] are several treatment options described for infected non-union with or without bone loss. All have improved results but none has been able to fully solve this clinical situation[13] . Though many methods have been employed to treat this situation, the Ilizarov ring fixator gives an option of compression, distraction and bone transport, and is effective in the treatment of infected non-union of tibia, even where other types of treatment have failed[14].

Ilizarov (1979) stated that a set of biological and mechanical conditions is essential for successful fracture treatment:

a) Preservation of blood supply of fracture site and the entire limb
b) Preservation of osteogenic (periosteum, endosteum, medulla) and other tissues in the moment of osteosynthesis as well as in consequent treatment
c) Active function of muscles, joints and entire damaged limb
d) Mobility of the patient in the first days of treatment.

SURGICAL ANATOMY OF LEG AND TIBIA[15]

A thorough knowledge of both topographic and the structural anatomy of the leg is essential in planning the operative approaches.

The muscles, tendons, ligaments and neurovascular structures in the leg are divided accordingly into anterior, lateral, posterior (superficial and deep) compartments for description and location.

Anterior compartment

Anterior compartment of leg contains muscles that dorsiflex the ankle. Boundaries are Tibia, Fibula, Interosseous membrane, Anterior intermuscular septum. The muscles are Tibialis anterior, Extensor digitorum longus, Extensor hallucis longus, Peroneus tertius. Deep peroneal nerve and the Anterior Tibial artery remain in this compartment. This is also called as the extensor compartment of the leg.

Lateral compartment

Lateral compartment contains muscles that evert the ankle joint. Boundaries are anteriorly, laterally and medially - crural fascia; posteriorly - anterior and posterior intermuscular septae, fibula. Muscles in this compartment are Peroneus longus , Peroneus brevis.

Superficial peroneal nerve lies within this compartment. Also called as the evertor compartment of the leg.

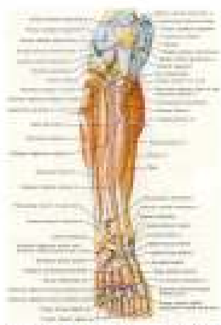
Posterior compartment

Posterior compartment contains muscles that plantarflex the ankle joint. Boundaries are anteriorly - tibia, fibula and interosseous membrane; laterally, medially and posteriorly - crural fascia. Contents are, superficial– Plantaris, Gastrocnemius, Soleus ; deep - Tibialis posterior, Popliteus, Flexor digitorum longus , Flexor hallucis longus. It also contains the posterior tibial artery , vein and the Tibial nerve.

PLATE - I

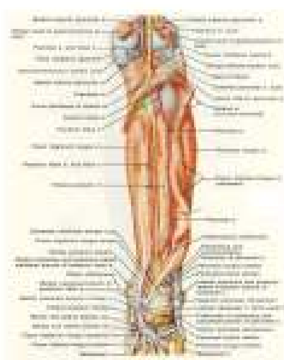
Anatomy of Tibia

Anterior Compartment
Superficial



Anterior Compartment
Deep

Posterior Compartment
Superficial



Posterior Compartment
Deep

Lateral Compartment

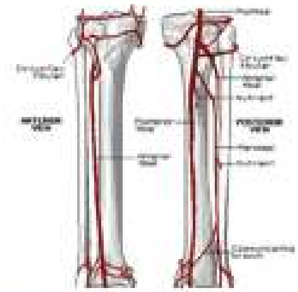
BLOOD SUPPLY [16]

The arterial blood supply of Tibia is derived from two sources:

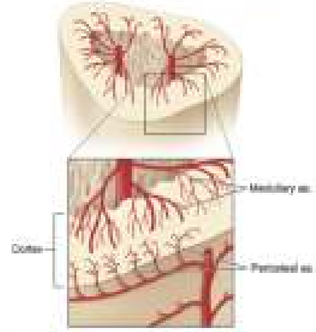
1.The main source of blood supply to the Tibial diaphysis is the Nutrient artery which arises from posterior tibial artery, it enters the posterolateral cortex of Tibia. Ascending branches are given after entering the medullary cavity. The descending branch remains as a single major vessel for some distance before dividing. The ascending and descending branches of the nutrient artery give off radial twigs that enter the cortex.

2.Periosteal blood supply is from the branches of the Anterior tibial artery. The periosteum has good vascular bed of the cortex. The epiphyseal-metaphyseal regions are mostly supplied by vessels entering from the periphery. Some of these capillaries traverse the cortex from periosteum to endosteum and anastomose with the branches of the nutrient artery. Ham described an additional anastomosis consisting of the vessels in the secondary Haversian canals. The venous drainage of the diaphyseal area is largely toward the endosteal surface through veins that accompany the arteries. At irregular intervals, however, venous channels also drain to the periosteal surface. The venous drainage of the epiphyseal region is by way of vessels adjoining the radially arranged arteries.

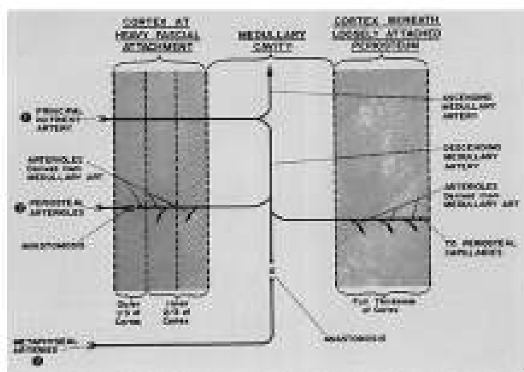
PLATE - 2



Blood Supply of Tibia



Cortical Blood Supply of Tibia



Distribution of Vascular System

CLASSIFICATION OF INFECTED NONUNION OF LONG BONES

Wieland's classification [17]

Type1: Bone exposed and soft tissue infection present

Type2: Circumferential cortical and endosteal infection present

Type3:Cortical and endosteal infection combined with segmental bone loss

Gordon's classification [18]

TypeA-Tibial defects and nonunions without significantsegmental loss

TypeB-Tibial defects greater than 3 cm with an intact fibula

TypeC-Tibial defects greater than 3 cm in without an intact fibula

Maurizio Catagni's classification [19,20]

A1-Non infected mobile nonunion

A2-Non infected stiff hypertrophic nonunion without deformity

A3-Non infected Hypertrophic nonunion with deformity

B1-Non infected nonunion with bone defect of up to 5 cms

B2-Non infected nonunion with bone defect exceeding 5 cms

B3-Non infected nonunion exceeding 10 cms with local scarring

C1-Infected nonunion with atrophy

C2-Infected nonunion with hypertrophy without deformity

C3-Infected nonunion with hypertrophy and deformity

C4-Infected nonunion with bone gap of less than 5 cms

C5-Infected nonunion with bone gap between 5 and 10 cms

C6-Infected nonunion with bone gap exceeding 10 cms

AO classification[21,22]

1.Infected non-draining nonunion. (Active/Quiescent)

2.Infected draining nonunion.

GENERAL PRINCIPLES IN MANAGEMENT OF INFECTED NONUNION OF LONG BONES [23]

Three entirely different methods of treatment have been recommended for the management of infected nonunion of the long bones.

1. Conventional or classic method
2. Active or modern method
3. Pulsed electromagnetic fields

Conventional or Classic Method

The objectives of the conventional method are to convert an infected and draining nonunion into one that has not drained for several months and to promote healing of the nonunion by bone grafting.The wound is thoroughly saucerized and all foreign, infected, or devitalized materials are removed to provide a vascular bed. The use of foreign materials in an infected fracture may be unwise. If plates and screws are used, almost always the drainage persists until they are removed, but they do allow the fracture to become stabilized by fibrous tissue in satisfactory position. An external fixator also can be used. This method is safer, but fixation is less secure than when a plate is used. Antibiotics are used parenterally and locally after surgery. Bone grafting is deferred until the soft-tissue graft has completely healed and has become stabilized. When the clinical signs of infection have subsided, the skin over the bone is good, and nonunion persists, bone grafting must be considered. Reconstructive operations usually should be delayed until at least 6 months after all signs of infection have disappeared.

Controlling infection before attempting bone grafting always has been a sound clinical principle in the conventional treatment of nonunions.

Active or Modern Method

The objective of the active method is to obtain bony union early and shorten the period of convalescence and preserve motion in the adjacent joints [24,25]. The first step is restoration of bony continuity. The ends of the fragments are decorticated subperiosteally, forming many small osteoperiosteal grafts, any grafts that become detached are discarded. All devitalized and infected bone and soft tissues are removed. Then the fragments are aligned and stabilized, usually by an external fixation device. Compression is applied across the nonunion if possible. Autogenous cancellous bone grafting can be done. Internal fixation with a plate is used only when drainage has already ceased, and then the approach is away from the area of old drainage, or when no other method of fixation is possible. Bone grafting can also be done in the presence of infection [26,27] .If necessary for union, a second decortication with or without the addition of cancellous iliac bone grafts is done [28] .Posterolateral corticocancellous bone grafting can be done for complicated and infected nonunions of the Tibial diaphysis[29] . Antibiotic-impregnated polymethyl methacrylate (PMMA) beads also can be used to treat infected nonunions. Heat-stable antibiotics, such as gentamicin or tobramycin , shall be mixed with PMMA and used locally to achieve 200 times the antibiotic concentration compared to intravenous administration [30,31]

Pulsed electromagnetic fields

This noninvasive method developed by Bassett et al. can be used in the presence of infection [32,33,34,35,36,37,38]. Two opposite coils of wire are mounted on the external surface of the cast or skin to deliver the pulsed electromagnetic fields. Weak, time varying currents are induced in the tissues as the pulsed electromagnetic waves pass through. This is similar to that formed by bone in response to any internal or external deformations. Calcification of gap tissue and result in bony union is triggered by these currents. The use of pulsed electromagnetic fields is a well known therapeutic method in the treatment of delayed and non-union of long bones.

AIM OF THE STUDY

The aim of the study is to analyse the bony union and functional outcome of Transosseous osteosynthesis by Compression-Distraction Osteogenesis in cases of infected non-union of fracture Tibia by the Ilizarov external ring fixation system.

REVIEW OF LITERATURE

Historical Review

1853-Malgaigne, described a simple unilateral external fixator frame.

1893-Keetley, recommended the usage of rigid pins for external fixator.

1897-Parkhill, described the use of two half pins above and two half pins below the fracture in long bones.

1900-Codivilla published the first result of a method of elongation of lower extremity[39].

1905-Codivilla , Lambert , Steinman and Hey Grooves attempted limb lengthening by double transfixation method.

1905-Codivilla of Bologna published, "to accomplish elongation of a lower extremity which was abnormally short as a result of injury, disease or malformation" by his own method by calcaneal pin traction and successive oblique osteotomies.

1911-Dr.O.Lambotte of France was the first to use the technique of distraction and transfixation.

1912 and **1917**-Lambotte and Humphry were the first to advocate the use of threaded pins.

1912-Magnusson performed a 'Z' lengthening of tibia, with traction and countertraction.

1913-Ombredanne[40] was the first to use an external fixator for limb-lengthening.

1918-Putti utilized Piano wires in his distraction apparatus.

1921-Putti[41] slowed the rate of distraction to two to three millimeters per day with a monolateral fixator and half-pins.

1927-The idea of a latency period to promote the formation of bone was introduced by Abbott[42].

Abbott's method became the standard in US. He did lengthening of TA, osteotomy of fibula, applied one proximal and one distal pin in tibia followed by application of distraction apparatus.

1929-Abbott's method was modified by Carrell and then by Brockway and Fowler to avoid anterior bending of the tibial fragments.

1931-Pitkn and Blackfield were the first to advocate pins inserted through both cortices.

1932-Dickson, Diveley, Haboush and Finkelstein used 'K' wires instead of Steinmann pins.

Haboush and Finkelstein were the first to describe an osteotomy of tibia without division of periosteum.

1933 to **1945-**Anderson and O'Neil of Seattle presented a series of papers concerning the use of half pins in leg lengthening procedures.

1936-Anderson[43] reported several innovations for femoral lengthening, including the use of wires attached to the apparatus under tension and technique for percutaneous osteotomy.

1938-Bosworth used Abbott's method of lengthening but suggested that distraction should not begin until 10 days after osteotomy or atleast until there was no evidence of hematoma or infection.

1938 to **1954-**Hoffman of Switzerland presented a series of articles describing his method of external fixation, his reports brought an upsurge in the popularity of external fixators.

1947-Phemister used on lay bone graft for treating nonunion

1951-Prof.G.A.Ilizarov proposed his method of Transosseous osteosynthesis in Kurgan, Siberia.

1952-Anderson introduced his method in 1952, by creating tibiofibular synostosis and then tibial lengthening was performed.

1958-Ring[44] distracted growth plates, observing that they fractured but that the periosteal sleeve remained intact and gave rise to a shell of new bone.

1967-Coleman, Noonan, Gross and Mitchell modified Anderson's method in order to achieve lengthening in one operation.

1970 to **1990-**Wagner[45] method of lengthening became more popular than the Anderson technique among most paediatric orthopaedists.

1979-DeBastiani introduced a new design of external fixator(Orthofix) and reported his results in 1984.

1982-The Association for the Study and Application of the Methods of Ilizarov (ASAMI) was established in Lecco, Italy.

1983-Prominent Orthopaedic Surgeons like Sarmiento exported Prof.Ilizarov’s work.

1986-DeBastiani et al., have applied Prof.Ilizarov's principles using a monolateral fixator that allows axial dynamization. While Prof.Ilizarov started distraction in 5 to 7 days, DeBastiani et al started at 14 days to allow for increased callus formation. This has been termed ‘CALLOTASIS’.

1990-Charles.T.Price et al., reported Ilizarov's method to be simple, safe and well tolerated by children and adolescents with moderate limb length discrepancy. But using this method for large defects and for adults was not supported by these authors[46].

Green, one of the pioneer in this subjects of nonunion has applied Prof.Ilizarov’s technique in the management of infected nonunion in United States.

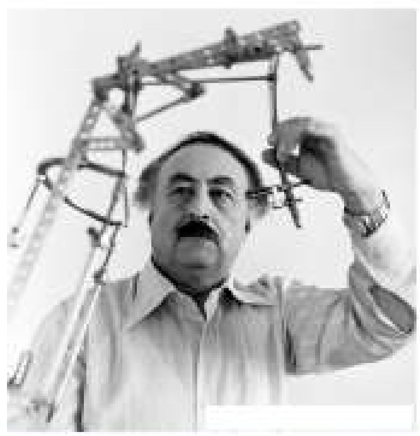
Prof. Gavril Abramovich Ilizarov

The concepts of segmental transport by Distraction osteogenesis and Transosseous osteosynthesis by compression-distraction Osteogenesis have been credited to Prof Gavril Abramovich Ilizarov, a Russian Orthopaedic Surgeon. It is said that one patient accidently turned the connecting rods between the rings in distraction. Ilizarov observed new bone formation radiologically following this distraction. Recognizing this, he initiated a series of experimental work in animals.

Professor Gavril Abramovich Ilizarov was born on 15th June,1921, in the town of Belovezh in the USSR. He got graduated from the Medical institute in Kazakhstan. In 1944 he was sent to Kurgan to work in a country hospital. Prof.G.A.Ilizarov became the Chief of the hospital's surgical department. In 1950, in a small village, Dolgovka, he performed his first operation using the ring fixator for a patient with 15 years old nonunion fracture Tibia . In 1952, he performed a 12.3cm limb lengthening with the help of the ring apparatus. In 1966, Prof.G.A.Ilizarov was appointed head of the laboratory. Prof.G.A.Ilizarov created an institute named “Kurgan Research Institute for Experimental and Clinical Orthopaedics and Traumatology” (KNIIEKOT). In 1969, Professor G.A.Ilizarov

PLATE - 3

Prof. Gavril Abramovich Ilizarov



Prof.Ilizarov with the Ring Assembly

published and defended his Ph.D. dissertation in title “Transosseous fixation by Avtor’s fixator”. Until the early 1980s the use of the Ilizarov external fixator remained in Russia. The new invention was brought to Italy by an orthopedic surgeon who had a nonunion fracture Tibia. After undergoing multiple surgeries which eventually failed, he travelled to Russia, where the fracture united in 3 months with the ring fixator.

Ilizarov method

According to Prof G.A.Ilizarov, to eliminate infection and obtain union, vascularity must be increased. The Ilizarov frame allows multiple modes of treatment, including compression, distraction, lengthening, and bone transport. In the Ilizarov approach, vascularity is increased by corticotomy and the application of a circular external fixator. Ilizarov method allows simultaneous treatment of all components, including angular, rotary, and translational deformities; shortening and segmental bone loss. This method is technically demanding and requires thorough training and experience. Deformities of 10 or 15 degrees can be corrected immediately by frame application; larger deformities should be corrected gradually.

Hypertrophic nonunions can be treated by gradual correction of the deformity, followed by compression. Atrophic nonunions with shortening can be treated by compression at the nonunion site accompanied by a corticotomy or cortical osteotomy in the metaphyseal region of the same bone and gradual lengthening through the corticotomy. Prof G.A.Ilizarov showed marked hypervascularity of the limb and bone after corticotomy and gradual distraction. Nonunions with segmental bone loss can be treated by corticotomy and gradual transport of a fragment.

Catagni recommended open debridement to remove necrotic and infected segments to eliminate infection before osteosynthesis. For hypertrophic nonunions with minimal infection and no sequestered bone, he recommended compression to increase formation of repair callus and vascularity. He reported that with this technique infection was spontaneously eliminated. Monofocal compression also is used for infected hypertrophic nonunions with deformity. For atrophic nonunions with diffuse infection or sequestered bone, open resection of the infected segment is performed, and bifocal compression is used [47,48].

Paley et al. reported successful treatment of 25 tibial nonunions with bone loss averaging 6.2 cm of bone, 13 of which had osteomyelitis. Union was obtained in all at an average of 13.6 months after application of the frame. Infection persisted in three patients, and amputation eventually was required in one patient [49,50,51].

Morandi, Zembo, and Ciotti reported that of 13 infected nonunions of the tibia, all united with no residual infection [52].

Pearson and Perry found the Ilizarov technique generally successful for treating nonunions with bone loss, but noted frequent minor complications, especially the need to freshen or bone graft the docking site after extensive bone transport [53].

Marsh et al. reported union of 40 of 46 nonunions and resolution of all 22 infections in their series. They advocated segmental excision of the nonunion site followed by distraction osteogenesis [54].

COMPONENTS OF ILIZAROV APPARATUS [55,56]

The elements of the Ilizarov compression - distraction apparatus can be divided into primary and secondary components.

Primary components are standard parts that join the skeleton to the finished frame, such as Transosseous wires, Rings and Wire fixation bolts.

Secondary components are the special elements used to construct the frame of the apparatus, such as Threaded and Telescopic rods, Connecting plates, Hinges, Posts, Nuts, Bolts and Wrenches [50]

RINGS [49]

The Ilizarov ring serves 3 main purposes

1) Supports transfixional'K' wires and/or half pins

2) Two or more connected rings form a frame of the apparatus

3) The rings bear supplementary parts of the frame necessary for dynamic bone treatment.

Half rings:

12 sizes of rings are available, each measured in its internal diameter in millimeters, ranging from 80,100,110,120,130,140, 150, 160,180,200,220 and 240 mm. Sizes 80 to 140 mm are used in paediatric patients and sizes 150 to 240 mm in adult patients.Each half

ring depending on its size, has 18 to 28 holes for the introduction of bolts or threaded rods. Each hole is 8 mm in diameter and the distance between the holes is 4mm.

Full rings:

Similar sized full rings are available. Full ring has some advantages over the connected half rings. It is slightly lighter because it does not require bolts and nuts to connect half rings and it has six more holes, which can be used for different purposes. The full ring does have some disadvantages. The full ring must be positioned before introduction of the wires. Once the wires have been introduced, the full ring cannot be placed over them.

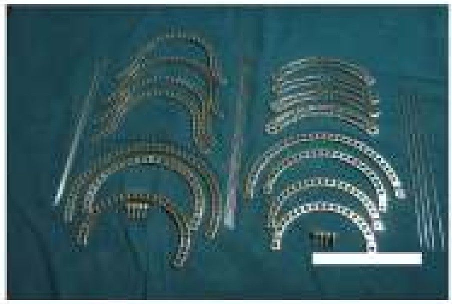
Five-eighths ring:

Available in three sizes 130,150,160mm in internal diameter. This configuration eliminates the normal circumference, thus permitting less restricted joint motion. There is more room for introduction of two cross wires. Indications for this usage include the existence of a myocutaneous flap, a large open wound with skin and soft tissue defect.

Half ring with curved ends:

Essentially a modified five-eighths ring in which the ends curve outward. This configuration fits perfectly the deltoid area of shoulder.

PLATE - 4



Primary Components

Secondary Components

Tensioner and Wrenches

ARCHES:

Russian Arch

Large-diameter semicircular arches with wide walls and double rows of multiple holes. This arch was constructed for upper femur fixation, with five to six wires at the level of the lesser trochanter.

Italian Arch (Dr. Catgni and Cattaneo's modification)

90 and 120 degree arches small and large sizes. 90 and 120 degree arch with slots for introduction of 2 or 3 half pins instead of wires, through the lateral and anterior cortex. They have slots divided into three sections by four clusters of holes which allow the half pin fixation, inserted at any angle to the transverse plane.

CONNECTING BOLTS AND NUTS:

All parts must be fastened together firmly with bolts and nuts in the assembly of any type of Ilizarov frame.

Connecting Bolts:

Three sizes of connecting bolts are available in a set. Common features are the threaded leg, 6 mm in diameter with a pitch equal to 1mm between each thread, and a standard 10 mm hexagonal head, 4 mm thick. The bolts differ from each other in length being 10mm, 16mm and 30mm.

10 mm bolt is too short to connect all types of parts. Used only for connecting the threaded sockets and bushings to the rings or connecting plates and for fastening the rods and half pins through the apertures of the socket, bushing and Ilizarov telescopic rod.

16 mm bolt is one of the most important parts of the set and is used to connect all main parts. The bolt is long enough to fasten two parts together and still allow space to tighten the nut.

30 mm bolt is used to connect three or more parts.

Nuts:

The smallest component of the set is a 10-mm nut which serves multiple purposes in the frame assembly. There are three sizes of hexogonal 10-mm nuts: 6-mm thick nut is known as full nut, 5-mm thick nut is known as the ¾ nut and 3-mm nut is known as the ½ nut. One thread pitch is equal to 1mm.So,6mm nuts have 6 threads, 5mm nuts have 5 threads and 3mm nuts have 3 threads. One full turn procuce 1mm monement on the rod. For distraction purposes, quarter turn four times a day is required.

The 6mm or full nut serves many functions in the frame.

1) Tighten the connecting bolts

2) Stabilize the connecting rod

3) Tighten the wire fixation bolt

4) Acts as a driven force for the ring in a Distraction - Compression movement

5) Lock the socket and/or bushing onto a threaded rod

6) Affix the pulling wire of a distraction device

7) Affix fixed positions of a male support

8) Secure hinge clearance

9) Secure a gap on a threaded rod

5mm or ¾ nut is mostly used for:

1)For frame stabilisation

2)For connecting two half rings

3)For bolt fixation

3mm or ½ nut is used for:

1)As supplementary nut for hinge construction

2)To lock 5mm nut in position

3)To secure a gap between two connected half rings

RING CONNECTORS – RODS AND PLATES

Seven types of ring connectors are available

1) Threaded rods

2) Partially threaded rods

3) Telescopic rods

4) Connecting plates

5) Graduated telescopic rods

6) Threaded sockets

7) And oblique support connections.

The first five are in the original set and the last two were added by Italian Orthopaedic group, and ASAMI.

RODS:

Threaded Rods:

The main type of connector in the Ilizarov system is the 6mm diameter stainless steel threaded rod. They come in 10 lengths: 60,80, 100,120,150,200,250,300,350 and 400mm. All rods share the same pitch, which equals 1mm. They have high strength characteristics for axial loading.

Biomechanically, four threaded rods provide much greater protection against bending than three rods do. The distance between two neighbouring rings must not be greater than the diameter of the ring.

Slotted Cannulated Rods:

This rod may serve as a connector and used as pulling device.

Telescopic Rod with Partially Threaded Shaft:

These telescopic rods are 100,150,200 or 250 mm in length.

Partially Threaded Rods:

Partially threaded rods are the same diameter as the fully threaded rods(6mm). But they have a smooth, unthreaded surface in the middle section. Sizes are 130,170,210mm in length.

Graduated Telescopic Rod:

The Graduated telescopic rod is an invention of ASAMI, Italy. It locks after the surgeon turns the device one-quarter turn. Square head have automatic locking system. It makes it easier for the surgeon to control the rate of distraction and compression.

Reduntant safety features are built into it ; has visual references on its square sides, and clicks audibly after every turn.

CONNECTION PLATES:

Required for the reinforcement of the frame and for foot oval assembly. There are 5 types of connection plates,

1. Short connection plate
2. Long connection plate
3. Connection plate with threaded end
4. Twisted connection plate
5. Curved connection plate

All plates are 5-mm thick,14-mm wide, and have 7-mm holes.

Short connection plate:

Available in nine sizes : 35 mm with two holes, 45 mm with three holes, 55 mm with four holes, 65 mm with five holes, 75 mm with six holes, 85 mm with seven holes, 95 mm with eight holes, 105 mm with nine holes and 115 mm with ten holes.

Long connection plate:

Used for connecting two rings.

Available in three sizes : 155mm with eight holes, 235 mm with twelve holes and 335 mm with seventeen holes.

Connection plate with threaded end:

Available in four sizes : 135mm with five holes, 175 mm with seven holes 215 mm with nine holes and 255 mm with eleven standard 7-mm holes.

Twisted connection plate:

Used for connection from horizontal to vertical planes. Their surfaces are at 90 degrees to each other. Available in three sizes : 45mm with two holes, 65 mm with three holes and 85 mm with four holes.

They also can be used to extend the frame outward.

Curved connection plate:

It increases the circumference of a half ring and connects frame areas where a straight connection plate will not fit. It is useful for foot and forearm frames.

THREADED SOCKETS AND BUSHING:

Threaded rods can be reinforced and lengthened by adding two types of connectors. Both mainly function as auxiliary connectors between two rods.

Threaded sockets:

Sizes 20 to 40 mm long and 10mm wide. They are hexagonal. Both ends of the socket canal are threaded for fixation to the bolts or to the threaded rods.

Bushing:

Bushing is a short 12mm long cylinder with a smooth, unthreaded aperture 7mm in diameter running through it.

SUPPORTS, POSTS AND HALF-HINGES:

Posts, supports and half hinges are auxiliary parts because they facilitate a variety of frame constructions. Their main advantages are:

1. They can be used at any location of the apparatus
2. They can be turned 360 degrees around their axis
3. They can be fixed in any desirable position.

Supports and Posts:

They are thicker than other parts because they bear tremendous loads. Supports are available in the following sizes : 28mm with two holes, 38mm with three holes and 48mm with four holes.

Posts are available as 30mm with two holes, 40mm with three holes and 50mm with four holes.

1.Male support has a 13 mm long standard threaded leg protruding from the butt end. This leg serves as a connection to other components. It is 4mm high at its base.

2.Female post has no protruding rod, but a 10 mm deep threaded hole at the butt end, serves to connect bolts and rods. It is 6mm high at its base.

Half Hinges:

Half hinges have a supporting base with two flat surfaces matching the standard 10 mm wrench. Two types are available:

1. Male half hinge has a standard threaded leg protruding from the base. This connects to other components.

2. Female half hinge has no leg, but a threaded hole at the base. serves to connect bolts and rods.

WIRE FIXATION BOLTS:

Fixes the K wires on the flat surface of the ring. To maintain a strong wire fixation, two types of bolts are used.

1.Cannulated wire fixation bolts

2.Slotted wire fixation bolts

Both the bolts are 6mm in diameter at the head, with 18mm threaded legs.

Slotted wire fixation bolt has an oblique slot on the side in the base of head.

The cannulated wire fixation bolt has a 2mm hole through it, just below the bottom of the head. Along with this hole is a 0.5mm groove, to accomodate the K wire.

Both types of wire fixation bolt permit introduction of a K wire into a hole or slot and also fixation of a K wire between the ring wall and the bolt head. The range of wire stiffness is between 200 and 300 kg. In general 1.5mm wire is more securely fixed with the cannulated bolt, and the 1.8mm wire with the slotted bolt. For optimal tightening, use of a regular 5mm nut is recommended.

WIRE FIXATION BUCKLES:

Wire fixation buckles are primarily used to affix K wires to the rings, but also used for multiple purposes during frame construction.

The principal advantage is that they can be used in ring locations where there are no accessible holes.Two types of wire fixation buckles are available.

1. Dual sided wire fixation buckles
2. Detachable wire fixation buckle.

The dual sided wire fixation bolt has the advantage that it can hold two K wires situated on two different planes.The advantage of detachable buckle is that it can be assembled and used at any ring position without being pre assembled.

WASHERS:

Washers may be used to fill the space between the various parts of the rings to provide lock-tight fastening. The washers differ in thickness and diameter, but all have 7mm hole in center. Six types of washers are included in the Ilizarov set.They are

1) 1.5mm thick, 12mm diameter
2) 2mm thick, 14mm diameter
3) 2mm thick, 20mm diameter
4) 3mm thick, 14mm diameter
5) 4mm thick, 14mm diameter
6) 3mm thick, 12mm diameter Conical washer couple

WRENCHES:

Nut-bolt and nut-ring tightening and loosening are performed with various types of wrenches. Tightening and loosening always must be done simultaneously with two wrenches. One wrench is attached to the motionless part(head of nut) and the second is attached to the part being tightened. This maneuver makes it much easier to produce the necessary tightening force, as much as 200kg.

WIRES [50]

Wires are the vital components of Ilizarov apparatus. Two different sized wires,1.5 and 1.8mm diameter is used. 1.5mm wires are used for children, 1.8mm wires for adults.

Two different tipped wires, Trocar and Bayonet tipped wires used.

Ilizarov wire with Bayonet point (For cortical bone)

The bayonet tip permits drilling across thick diaphyseal cortex without overheating. The tip is equal in the diameter of the shaft to maximise a tight fit within bone.

Ilizarov wire with Trocar point (For cancellous bone)

The trocar point permits better directional control when drilling across primarily cancellous bone such as metaphyseal or epiphyseal segments.

Wire with Stopper (Olive wire)

Olive or Stopper wire with a support bead provides interfragmentary compression, increases stability of the construct, allows gradual distraction or translation of bone fragments.

WIRE TENSIONER [50]

The Tensioner is a very important instrument which allows one to tension the wires to an exact force, improving stability of the bone-frame construct. The wires should be tensioned from 50 to 130 kilograms. The exact amount of tensioning depends on the weight of the patient, the local bone quality, treatment plan and the local frame construct.

1. Simple wire tensioner

Tensioning the wire with the original Ilizarov tensioner involves first fixing the wire to the ring with a bolt. The tensioner is then fixed to the ring to keep it from sliding about the ring. Turning of the wing-nut clock wise applies tension to the wire.

2. Dynamometric Wire Tensioner

The parts of the dynamometer

a)Handle for applying tension,

b)dynamometer scale from 50 to 130 kg,

c)fixed jaw and

d)mobile jaw.

The advantage of the dynamometric wire tensioner is that consistent tensioning can be done.

OTHER COMPONENTS [49]

Half pins of size 4 to 6mm in diameter are used,require predrilling. Half pin fixation bolts and Rancho cubes are other important components in Ilizarov system.

BIOMECHANICS OF ILIZAROV APPARATUS

The biomechanics of Ilizarov method have a fundamental distinction from other types of external fixators. It consists of careful approach and particular attention to preservation and stimulation of local and regional blood circulation. Ilizarov's fixator comprises of a modular ring fixator which uses smooth, tensioned 1.5 and 1.8 'K' wires for multilevel, multiplanar and multidirectional transosseous fixation of fractures.The wires combined with the rings allow the optimal biomechanical characteristics for the bone fragment stabilisation [53] . The exact strength of tensioning depends on [50] :

1. Weight of the patient (Child versus Adult).
2. Local bone quality (Osteoporotic versus Normal bone).
3. Functional wire loading(Stabilization versus Compression Distraction).
4. Local frame construction (half ring versus full ring),
5. (offset versus main ring wire).

The range of wire tensioning strength is 50 to 130 kg [51]:

a) Wire on half-ring : 50 to 70 kg.

b) Offset wire : 50 to 80 kg.

c) 2 to3 wires on a ring in a child : 100 to110 Kg

d) 2 to3 wires on a ring for an adult patient :120 to 130 kg

The Ilizarov external fixator exhibits more isotropic mechanical properties in bending, non linear axial stiffness, and the ability to readily create configurations for complex corrections.

Stability of Ilizarov external fixator depends on:

I. Extrinsic factors

They are apparatus related factors identified to increase the stability of the fixation:

1.Spread between crossing wires approaching 90/90 degrees

2.Increased wire diameter

3.Increased wire tension

4.Decreased ring size

5.Use of Olive wires

6.Increased number of wires

7.Close positioning of center rings to fracture/ nonunion site

II. Intrinsic factors

Intrinsic factors contributing to the stability are

1. Area of tissue contact between bone ends.
2. Modulus of elasticity of tissue between bone ends.
3. Length of gap between bone ends.
4. Mechanical configuration and interlock between bone ends.

5. Tension of soft tissues surrounding bone.

The Ilizarov apparatus is axially elastic and as the weight bearing forces are directly applied to the bone ends, maintaining the weight bearing function of the extremity actually is the principle behind the success of this method. The cyclic axial telescoping mobility, not rigidity, at the non-union or fracture site is an important requirement for the formation of a reparative callus. Ilizarov experimentally showed that when gradual distraction tension stress is applied to the corticotomy site, the vascularity of the entire limb is increased, which in turn enhances the ability of the bone ends to unite.

In limb lengthening and deformity correction, Ilizarov method has numerous advantages compared with other methods[57]. Modular design of the fixator allows each apparatus to be custom-fit for the individual. The use of 1.5 to 1.8-mm pins produces fewer pin-track problems than other conventional methods of limb lengthening, which use larger diameter half pins. Smaller diameter and tensioned wires are virtually stable to withstand dynamic loading of the lengthening segment, which experimentally has been shown to be favourable for fracture gap healing. The circular configuration of the frame enhances stability while ensuring that stress is evenly distributed across the corticotomy and distraction gap. This biomechanical combination of frame stability and axial elasticity allows for weight bearing throughout the limb-lengthening and consolidation periods while ensuring osteogenesis across the distraction gap [58,59].

Acute shortening can be accomplished safely for defects up to 3 to 4cm in the Tibia [60]. Gradual or acute shortening at the fracture site has advantages over bone transport. It helps by decreasing tension and gaps in the open wound, shortening the time period in the frame. It is recommended in patients with severe peripheral vascular disease, diabetes mellitus, and connective tissue disorders[61]. Acute shortening more than 4cm in the Tibia can lead to tortuous vasculature and may produce a low flow state leading to poor results. Significant oedema and the possibility of additional tissue necrosis and infection are possible when open soft tissue wounds are acutely compressed because the soft tissues become bunched and dysvascular[62,63].

Thus the three theoretical and biomechanical foundations of Ilizarov method are,

a) Minimal damage to vascularity,

b) Elastic stabilization of fracture site,

c) Immediate resumption to function.

BIOLOGY OF DISTRACTION OSTEOGENESIS

DEFINITION:

Distraction osteogenesis is the mechanical induction of new bone between bony surfaces that are gradually pulled apart after a low energy osteotomy. Distraction osteogenesis is controlled externally by a ring fixator. The biological bridge between these bony surfaces arises from local neo vascularisation and spans the entire cross section of the cut surfaces. During distraction , a fibrovascular interface is aligned parallel to the direction of distraction while new bone columns add length to the gap. When the biological and mechanical conditions during distraction are ideal, bone is formed by pure intramembranous ossification.

Corticotomy is a low-energy osteotomy with transection of only the bone cortex. The periosteum, endosteum, and the bone marrow with its blood supply, as well as the muscles and soft tissues surrounding the bone are maximally preserved. A Corticotomy is best described as an open subperiosteal partial osteotomy of the bone cortex.

Paley et al. described an effective method of corticotomy in which a 5-mm osteotome is used to cut the cortices, extending subperiosteally into the corners. The fixator rings above and below can be rotated to complete the corticotomy. On radiograph, the corticotomy should appear as a non displaced osteotomy. Power saws and high-speed burrs can cause thermal necrosis of the bone ends and adjacent soft tissues. Low energy options are the osteotomes and the Gigli Saw. Periosteum, endosteum and cortical bone all have shown to contribute for the regenerate, with the periosteum considered most important.

1.Classic Method

A percutaneous subperiosteal cortical osteotomy. This technique is performed with an osteotome in two different methods.

a) Triangular bone method – For Tibia, Ulna and Radius

b) Round table method – For Femur and Humerus

2. Percutaneous Gigli saw method

Used for Tibial corticotomy. A Gigli saw is passed subperiosteally around the Tibia. With protection to the periosteum, the bone is then transected.

The quality of the regenerate after corticotomy depends on certain mechanical factors. They are

1.Rate or speed of Distraction: It is the number of mm the bone surfaces are distracted apart after corticotomy. The optimum rate or speed of distraction is 1mm per day, equally divided, 0.25mm every six hours.

2.Rhythm: It is defined as the number of actual distractions each day. Optimum rhythm is 4 times a day.

So there must be four distraction adjustment daily at 6 hours interval. With each adjustment there will be 0.25mm or one fourth of thread pitch movement.

3.Latency: It is the time period between the operation and the initiation of distraction.

Jorge.E.Alonso [64] and Pietro Regazzoni have divided the period of distraction osteogenesis into three phases :

1. Transport phase
2. Maturation phase
3. Consolidation phase.

TRANSPORT PHASE

This phase is the period from the initial advancement of the segmental defect till the end of the transported segment comes in contact with the other fragment . Ilizarov has demonstrated that intramembranous ossification occurs during distraction.

MATURATION PHASE

During this phase, an increase in mineral content of the regenerate area can be seen.

CONSOLIDATION PHASE

This is the phase in which the cortical bone content increases to about 80% according to Prof. Ilizarov.

Histology

Biopsies were taken from the mid-sagittal plane along the tibia crest. A Bronwill saw was used to section the bones.

From Day 7 of distraction(Post Op day 14): Fibrovascular network, no evidence of new mineralisation.

From Day 14 of distraction(Post Op day 21): New bone seen forming at the two cut surfaces of the corticotomy.

From Day 21 of distraction(Post Op day 28):New bone differentiated into microcolumns. The central region remained the Fibrous interzone.

Post Op day 77: The osteogenic area remodelled, demonstrating early cortex formation.

Post Op day 119: The Osteogenic area contained lamellar bone with Haversian systems and hematopoietic marrow.

Vascular studies

India ink injection into the regenerate on day 35 demonstrated both afferent and efferent vessels across the osteogenic area. In coronal section, very few vessels crossed the fibrous interzone. The vessels were clearly oriented parallel to the distraction force and the new columns of bone. Technetium scintigraphy provided an in Vivo measurements of blood flow and bone formation relative to the opposite Tibia.

Mineral density studies

Quantitative computer tomography(QCT) delineated the different histological zones of mineralisation. Calcium quantification of two-millimeter transverse sections through the osteogenic area.

Radiographic classification of the Bone Regenerate

1. Normotrophic Regenerate - Early radio dense new bone formation approximately 20 days after the corticotomy. Definite columns of longitudinally oriented new bone appear extending with a central transverse radiolucent area. The regenerate should maintain a constant diameter radiographically.

2. Hypertrophic Regenerate - Appears before the 20th day. The cross sectional diameter of regenerate exceeds that of the corticotomy site.

3. Hypotrophic Regenerate – Regenerate delayed in its radiographic appearance.

There are 4 types of Hypotrophic regenerate.

Type A : Spotty radio densities persist after day 50, indicating poor vascularity.

Type B : Hourglass configuration indicates that distraction rate is too fast.

Type C : Irregular regenerate bone columns may indicate instability or vascular insufficiency.

Type D : Focal failure of bone formation indicates a local vascular Injury or periosteal damage if peripheral.

Other imaging techniques for evaluation of regenerate:

Ultrasound evaluation

Technically, a "real-time" unit is utilized in combination with a sectional probe. Longitudinal sections are performed first along the length of the regenerate. This provides information about the total lengthened distance as well as the quality of the regenerate. Transverse sections are obtained which provide valuable information about the volume of the regenerate. The technique should probably be considered an adjunct to regular radiographic assessment.

MATERIALS AND METHODS

Study Topic : Management of infected nonunion fracture Tibia by Transosseous osteosynthesis with Ilizarov's external ring fixation system.

Study Design : Prospective study.

Study Period : May 2009 to October 2011.

Sample Size : Twenty patients

Inclusion Criteria: 1.Cases of infected nonunion Tibia with active infection

2.Cases of infected nonunion Tibia without active infection

PRE OPERATIVE PROTOCOL

Examination

A thorough clinical examination was done as per predesigned and pretested proforma which includes age, sex, general condition, occupation, mode of injury, type of fracture, initial treatment, Duration of treatment, number of surgical procedures, months after injury, associated co-morbid conditions. Evaluation of the affected limb for active infection, Abnormal mobility, Range of movements, limb length discrepancies, Fixed deformities, Joint stiffness, Neurovascular deficit.

Investigations

Routine investigations like Haemogram, Blood sugar, urea, creatinine, serum electrolytes, X- ray Chest , ECG, BT, CT done. All the patients were medically fit for anaesthesia and surgery.

X-Rays

X-ray leg AP / Lateral view from the knee to ankle joint was taken for all the 20 cases and following features were assessed : Type of nonunion, evidence of infection, presence of sequestrum, bony defect, deformities at the fracture site, status of fibula.

Pre operative Planning

The level of the rings, number of wires, the angle of wire insertion in correspondence to the topographic anatomical atlas were marked using a trace paper. The amount of shortening measured. Any neurovascular deficiency, joint stiffness, contractures documented. Clinical photograph of the patient and the affected limb were taken for further documentation.

Frame Construction

Two half rings, 4 cm larger than the major diameter of the injured limb was selected. Tibial fractures required 140,160,180 sized rings. The rings are positioned in the same plane and a bolt and nut anchored together at both ends of the half rings. A 4 ring assembly was used with 2 rings proximal and distal to fracture site. Two rings were used on large fragments. Drop post or drop wire used for shorter segments. Two proximal & distal rings were connected with threaded rods of appropriate length .

Surgical technique

Anaesthesia - Spinal anaesthesia.

Position – Supine, with sand bag or a flat object under the thigh and the heel leaving the entire operating area free.

Surgical Strategy

Power drill was used for wire placement. The pre assembled ring apparatus introduced into the affected leg. Wires were passed along and at angle according to the safe corridor corresponding to the topographic anatomical atlas.

For simple fractures one ring with two crossed wires and supplementary drop wire was used proximally and a similar combination distally. For more stable configuration the fibula is incorporated with the ring assembly. Fibula fixation is contraindicated at the level of fibular neck for fear of peroneal nerve damage.

First the proximal most end of the apparatus was fixed with K wire, then the distal most. The first K wire was passed through the head of fibula. The second ‘K’ wire was passed through Tibia from

PLATE - 5

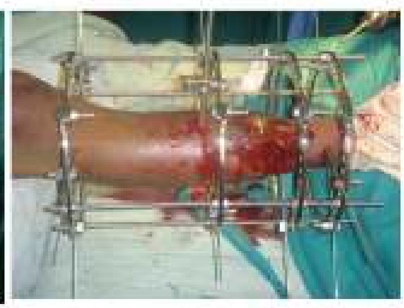
Pre Op X ray with sequestrum

Removal of the sequestrum at the fracture site

Introduction of the Pre assembled ring

Reference wire transfixing the Fibular head and Tibia

Reference wire transfixing the lateral malleolus and Tibia



Final ring assembly

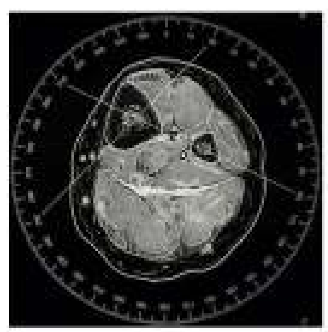
PLATE - 6

Tibial Cuts - Left Tibia

Cut 0

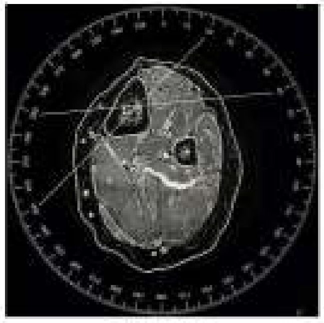
Cut 4

Cut 8

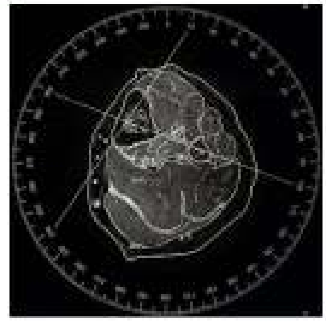


Cut 12

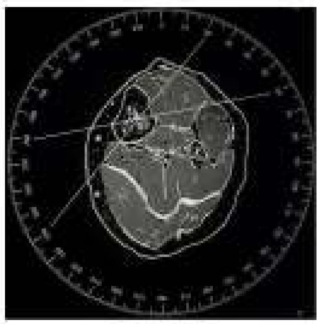
PLATE - 7



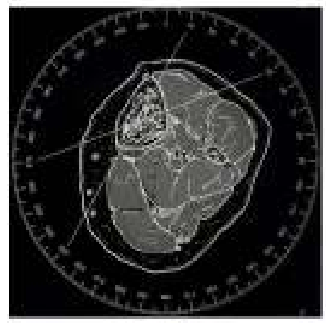
Cut 16



Cut 20



Cut 24



Cut 28

Cut 32

Cut 36

anterolateral to posteromedial direction. Both the wires were attached to the ring with wire fixation bolts and the wires were tensioned. Wire tensioning was done with dynamometric wire tensioner in most of the cases while manual tensioning was used in some cases. The distal most ring was fixed with two ‘K’ wires, one transfixing the lateral malleolus with the Tibia and the other through the anteromedial surface of the Tibia. Fracture was reduced and aligned either by closed or open method.The intermediate loose rings were connected with proximal, distal rings by connecting rods.Then intermediate rings were fixed with 2 ‘K’ wires/olive wires according to topographic anatomical atlas. Wires were manipulated accordingly to reduce the displaced fragments. Bayonet pointed 1.8mm ‘K’ wires were used in diaphyseal region and 1.8mm Trocar pointed wires were used at the cancellous areas. Olive wires were used to correct translation, displacement and to achieve interfragmentary compression. Corticotomy was done using Osteotome, Corticotome at the proximal metaphysis for correction of shortening or bony defect. After checking with C-arm, compression was given at fracture site. We used Betadine for each pin site dressing.

POST OPERATIVE MANAGEMENT

The patient leaves the operating room with his/her limb elevated. The wire skin interface was protected by a piece of gauze. Parenteral antibiotics were given for the first seven to ten days. Active and passive hip, knee, ankle mobilisation and Isometric quadriceps exercises were started at the first post operative day.

Weight bearing is started as tolerated by the patient from third to fifth day.

The patient was taught about the pin site care, mobilisation and walking exercises and periodic tightening of the ring assembly.

Patients were followed up every fortnight.,reviewed and were treated accordingly to the following conditions

1. Wire loosening and breakage
2. Pin site infection
3. Joint stiffness
4. Neuro vascular deficit
5. Shortening and Deformity

Radiological Evaluation

Radiological evaluation done at the interval of three weeks for evidence, amount and quality of callus and the regenerate.

Also they are evaluated for any angulation or translation at the fracture site.

COMPLICATIONS

Problems, obstacles, and complications that may arise with the llizarov technique during limb lengthening include muscle contractures, joint subluxation, axial deviation, neurological or vascular insult, premature consolidation, delayed consolidation, refracture, pin-site infection, and difficulties with psychological adjustment.

The complications may be divided into the following:

a. Intra-operative complications

b. Immediate postoperative complications

c. Late postoperative complications

Intra-operative complications

Neurovascular - These are usually due to errors related to wire placement and position, malreduction of the fracture, soft tissue problems – Difficult wound closure.

Immediate postoperative complications

Pain at the pin bone interface, oedema of the operated limb, Loss of fracture reduction,

Late postoperative complications

Loss of fracture reduction, Dermatitis, Poor fracture consolidation, Joint stiffness, Nonunion, Persistent infection and Refracture.

REMOVAL OF THE APPARATUS

When the patient was able to walk without pain, when there was no fracture site tenderness and when the x-rays revealed a good radiological union at non-union site and consolidation of regenerate, unscrewing the nuts of the threaded rods or loosening of the tensioned wires was done. The patient was reviewed after two weeks of weight bearing. If the patient experienced no discomfort with weight bearing, the apparatus was safely removed. The wires were cut 1 to 2 centimeters outside the skin, the apparatus slipped off the limb and the skin disinfected. The wires were then removed.

OBSERVATIONS

Table 1: Sex distribution of the patients

Sex	*No. of patients*	*Percentage*
Male	19	95 %
Female	1	5%

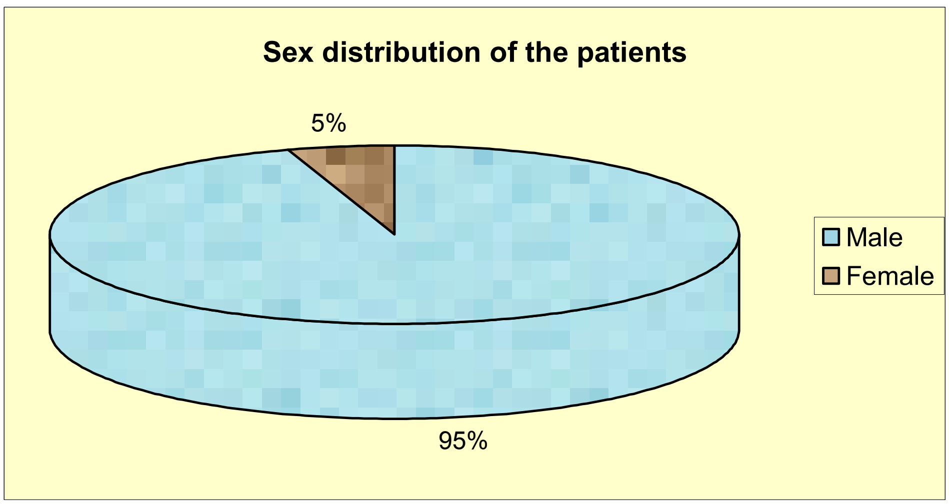


Table 2: Age of the patients

Age	*No. of patients*	*Percentage*
20 to 30 yrs	3	15%
30 to 40 yrs	7	35%
40 to 50 yrs	7	35%
50 to 60 yrs	2	10%
60 to 70 yrs	1	5%

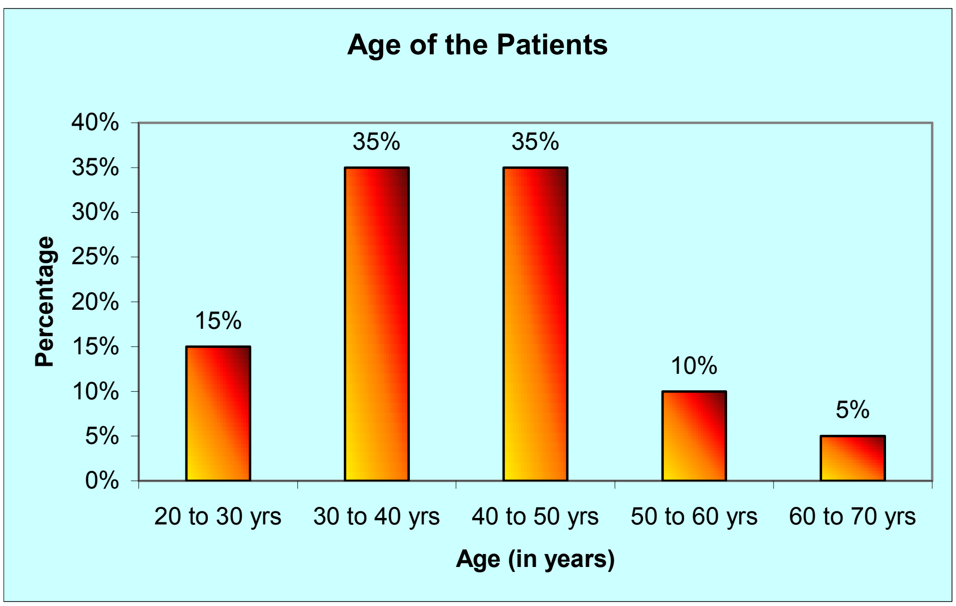


Table 3: Side of the affected limb

Side	*No. of patients*	*Percentage*
Right	14	70%
Left	6	30%

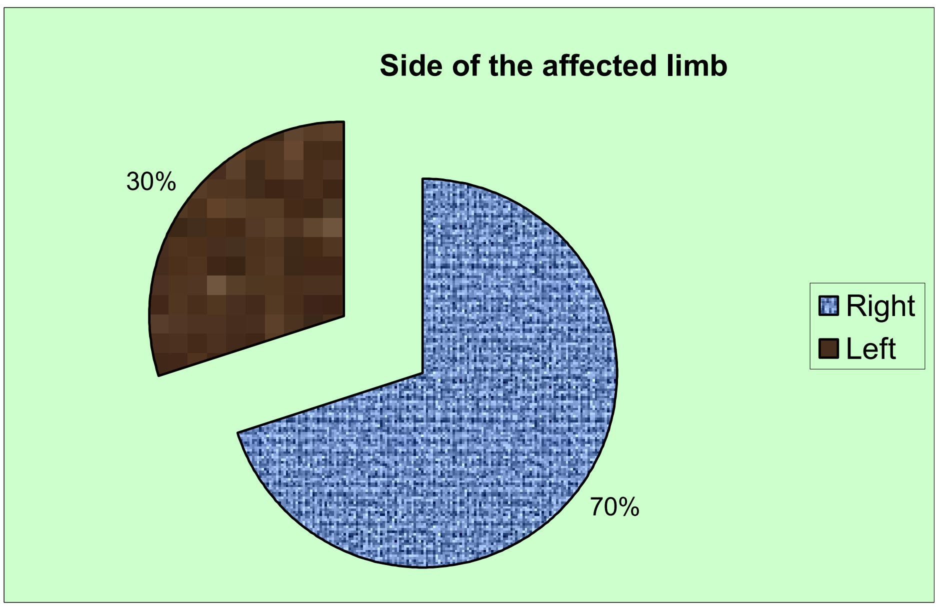


Table 4: Associated comorbid conditions

Co-morbid conditions	***No. of patients***
Diabetes Mellitus	4
Hypertension	1
Others	1

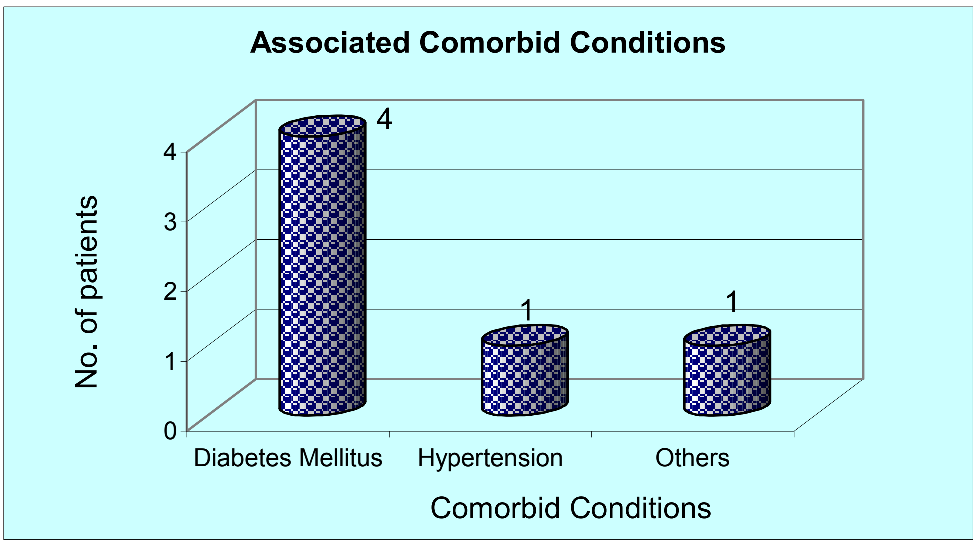


Table 5: Mode of injury

Mode of injury	*No. of patients*	*Percentage*
Road traffic accident	19	95%
Accidental fall	1	5%
Others	-	-

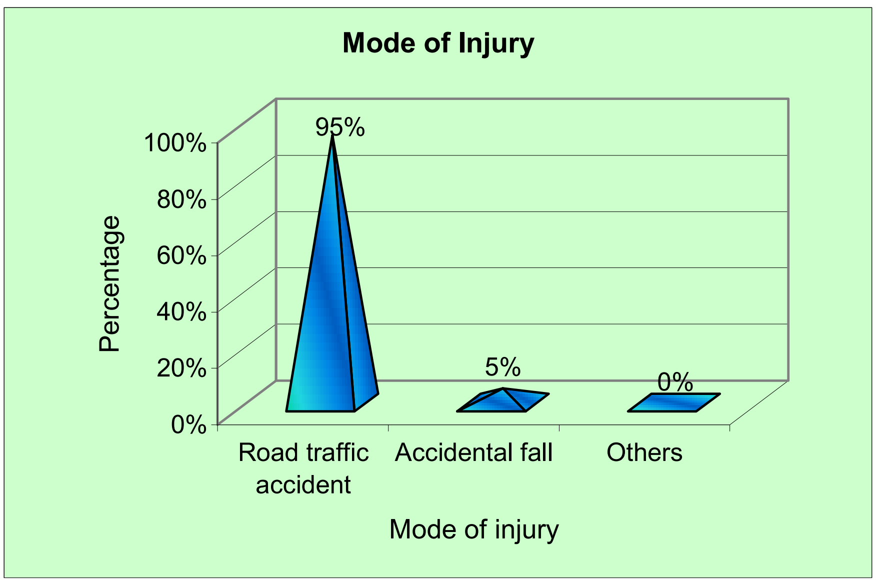


Table 6: Descriptive statistics for the Primary fracture according to Classification

Type of fracture	*No. of patients*	*Percentage*
Closed	8	40%
Open	12	60%

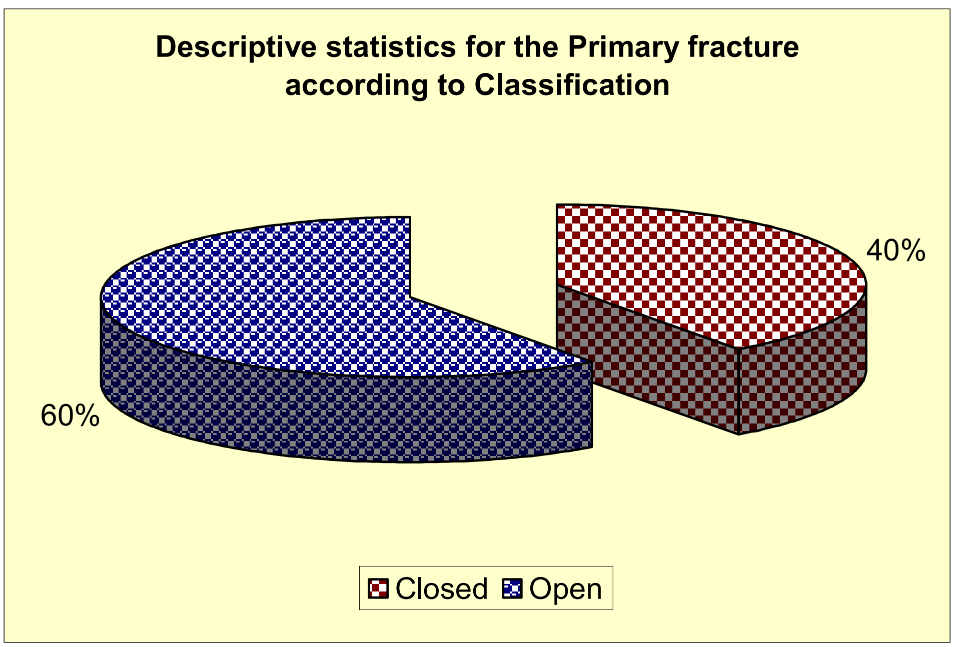


Table 7: Modified Gustilo Anderson's classification

Modified Gustilo Anderson's classification	*No. of patients*
Grade 1	-
Grade 2	-
Grade 3A	-
Grade 3B	12

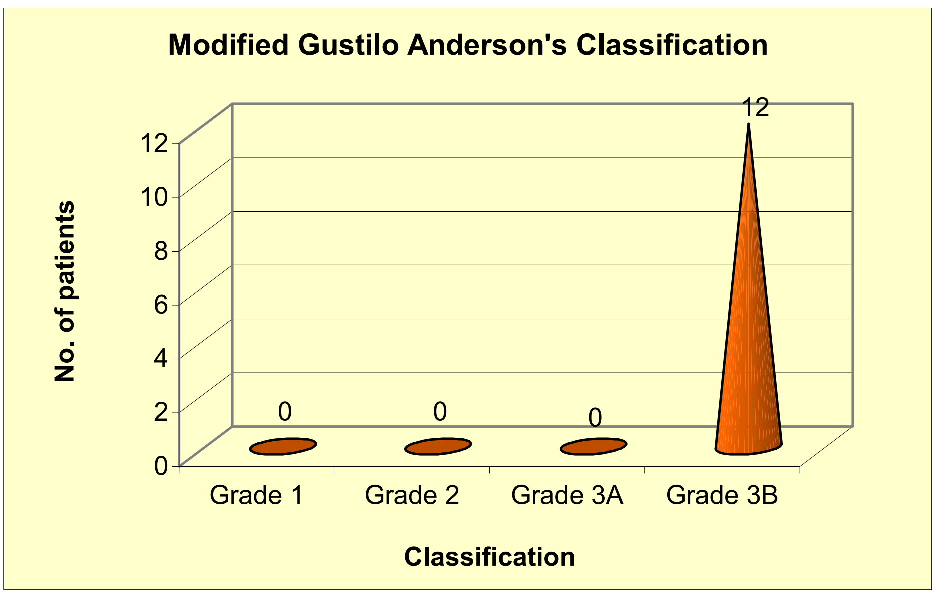


Table 8: Level of fracture

Level of fracture	*No. of patients*	*Percentage*
Proximal third	2	10%
Middle third	10	50%
Distal third	6	30%
Segmental fracture	2	10%

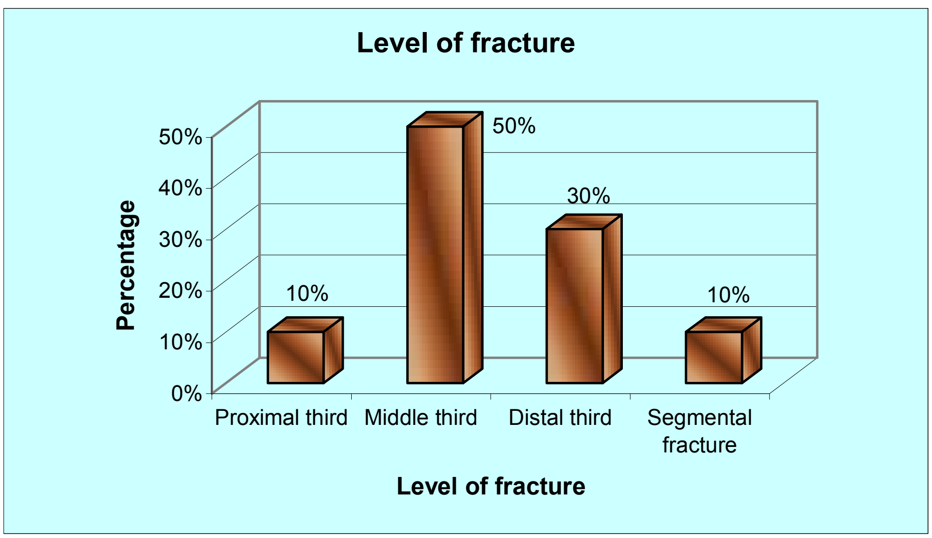


Table 9: Initial fracture fixation

Mode of fixation	*No. of patients*	*Percentage*
Conservative	1	5%
Interlocking Nailing	3	15%
External fixation	13	65%
Plating	2	10%
Native treatment	1	5%

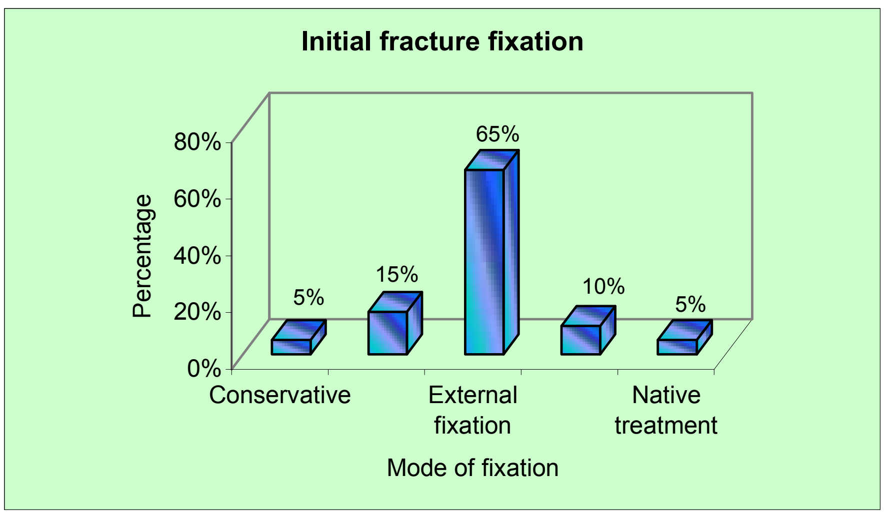


Table 10: Additional procedures

Procedures	*No. of patients*
Myocutaneous flap	8
Skin grafting	3
Others	-

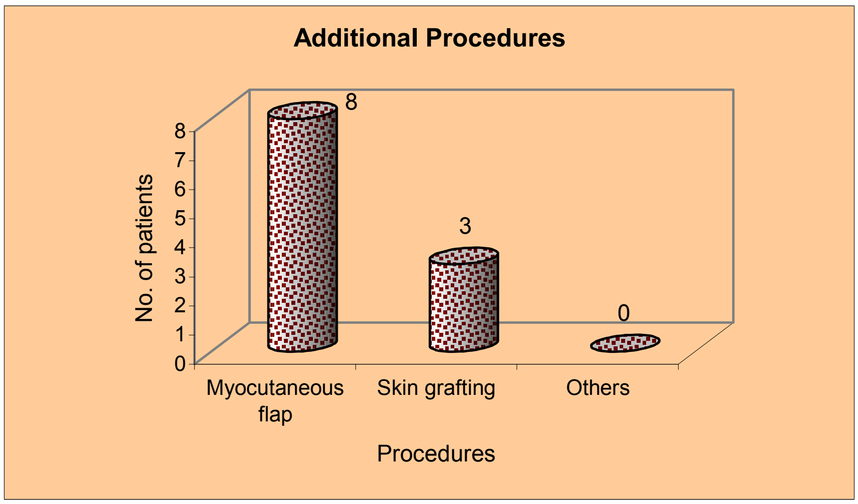


Table 11: Complications

Complications	*No. of patients*
Pin Tract infection	4
Post operative edema	6
Nerve injury	1
Dermatitis	1
Equinus	2
Knee stiffness	1
Persistent infection	1
Nonunion	3

Observations in our study:

- Majority of injured patients were males (95%).
- Females had little acceptance to the ring fixator culturally.
- Highest number of patients were between 30 and 50 years of age (35% each).
- RTA was the most common mode of injury (95%)
- Majority of the injured patients were with open, Gustillo type IIIB (60%).
- Right Tibia was fractured more frequently (70%).
- Diaphyseal fractures were common among the fractures (50%).
- Early complications encountered were pin tract infection, pain, limb edema and wire loosening and dermatitis.
- Late complications were Equinus deformity, Knee stiffness, persistence of infection, nonunion.

CASE ILLUSTRATION

CASE 1: 28 Years, Male, Sustained Grade 3B open fracture both bones middle third right leg, two and a half years back. Initially the fracture was managed with wound debridement and a conventional AO tubular external fixator, by myocutaneous flap with the external fixator in situ after two months of injury. The external fixator was removed and a below knee cast was given on discharge. He presented to us with hypertrophic nonunion fracture middle third right Tibia, without any active infection. He was treated by us with debridement of the necrosed fracture ends and acute docking at the fracture site since the bony defect was less than 2cm.

The fracture got united in 6 months with a shortening of 2cm. The Ilizarov apparatus was removed. There was no stiffness of the joints, no deformities or any other complications.

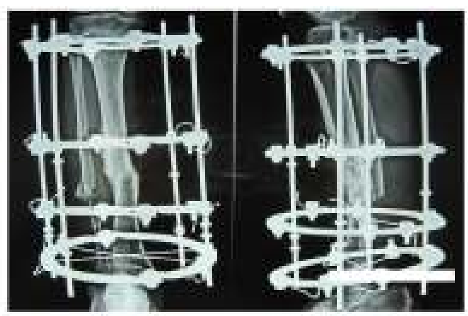
PLATE - 8

Pre Op X ray - Hypertrophic nonunion Middle Third Tibia

Patient with Ilizarov fixator

Right Leg on Ilizarov fixator

Post Op X ray - Resection of the necrosed bone segments and acute shortening



Post Op X ray Showing solid bony union

PLATE - 9

Functional outcome-
No stiffness of the joints

Functional outcome-Knee flexion

Post Op X ray showing bony union after
removal of the Ilizarov fixator

Functional outcome - 2cm LLD

Functional outcome-Full
Knee extension

CASE 2: 38 Years, Male, sustained a Grade 3B open fracture both bones middle third left leg three years back. Initially he was treated immediately with Wound debridement and External fixator application. There was pus discharge from the fracture site. He presented with infected nonunion middle third left Tibia with active infection. He was treated with sequestrectomy and in situ Ilizarov fixator application. Then compression given at the fracture site between the fracture ends. The pus discharge from the fracture site was decreased gradually and the fracture went on to unite in a period of five months. After fracture union, there was no shortening of the fractured limb. The range of movements of the joints were near normal, without stiffness of joints of the affected limb.

PLATE - 10

Pre Op X ray Left Tibia
AP view with a Sequestrum

Pre Op X ray Left Tibia
Lat view with a Sequestrum

Left leg with active infection

Post Op X ray AP view
after removal of the sequestrum

Post Op X ray Lat view after
removal of the sequestrum

PLATE - 11

Clinical photograph of the patient

Functional outcome-No LLD

Functional outcome - Knee Flexion

Functional outcome-Full range of movements

Post OP X ray with Solid union of the Tibia

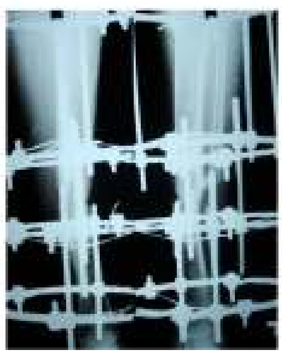
CASE 3: 28 Years, Male, sustained Grade 3B open fracture both bones middle third left years back, Initially he was managed with External fixator and later a myocutaneous flap was applied with the external fixator. He presented with nonunion fracture middle third left Tibia with mild infection, three months after injury. He was managed with necrectomy and the external fixator continued. Then the external fixator removed. Acute docking of the fracture site done after applying the Ilizarov ring fixator. The fracture united well with a shortening of 2cm. There was no associated deformities, complications. The range of movements near normal, without stiffness of the joints.

PLATE - 12

Pre Op X ray-Leg On External fixator

X ray-After necrectomy

Leg On External fixator



Post Op x ray-Solid bone union with Ilizarov fixator

Post op X ray showing solid bone union

PLATE - 13

Functional outcome

Functional outcome-
No stiffness of the joints

Functional outcome-LLD <2.5 cm

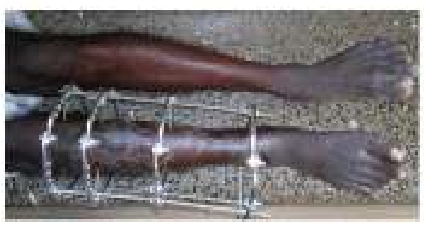
Functional outcome-Knee flexion

CASE 4: 49 yrs, Male, sustained a closed fracture both bones proximal third right leg two and a half years back. Initially he was treated with Open reduction and internal fixation with Narrow dynamic compression plate and screws. The bone got infected and the skin flap necrosed, ultimately exposing the plate. A myocutaneous flap was applied at the fracture site then. The infection persisted and there was continuous pus discharge from the fracture site. He presented with infected nonunion Tibia proximal third with active infection. He was treated with plate removal, debridement of the fracture ends, acute shortening and Ilizarov fixator application. Compression was given at the fracture site. The fracture went for union after seven and a half months with the Ilizarov fixator and there was complete elimination of infection at the fracture site. A shortening of 2cm was noted after fracture union with an equinus deformity of five degrees.

PLATE - 14

Pre Op X ray AP - Tibial Plating with Nonunion

Pre Op X ray Lat - Tibia Plating with Nonunion



Right leg on Ilizarov fixator

Post Op X ray

PLATE - 15

Patient on Ilizarov fixator

Post Op X ray with
Bony union of Tibia

Functional outcome- Knee flexion

Functional outcome-LLD <2.5cm

RESULTS

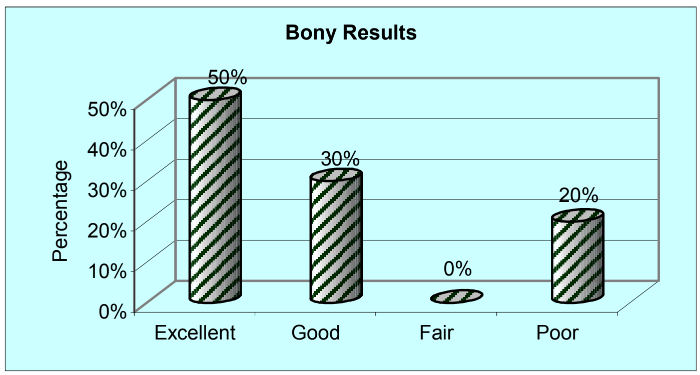
Results were analysed based on the ASAMI Scoring system[65]

ASAMI SCORING SYSTEM

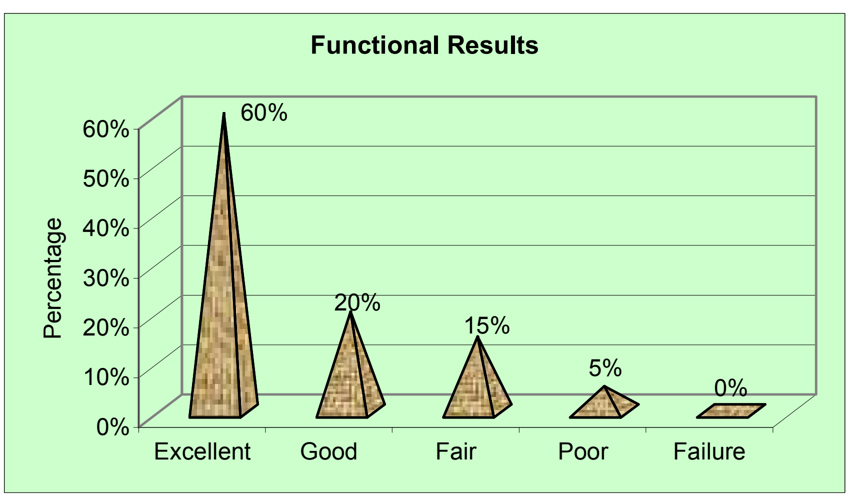
Bone results	
Excellent	Union, no infection, deformity<7°, limb length discrepancy<2.5 cm
Good	Union + any two of the following: no infection, deformity<7°,limb length discrepancy<2.5 cm
Fair	Union +only one of the following: no infection, deformity<7°,limb length discrepancy<2.5 cm
Poor	Non union / refracture / union + infection + deformity>7° + limb length discrepancy>2.5 cm
Functional results	
Excellent	Active, no limp, minimum stiffness(loss of <15°knee extension <15°dorsiflexion of ankle),no reflex sympathetic dystrophy, insignificant pain
Good	Active with one or two of the following: Limp, stiffness, RSD, significant pain.
Fair	Active with three or all of the following: Limp, stiffness, RSD, significant pain
Poor	Inactive (unemployment or inability to return to daily activities because of injury)
Failure	Amputation

The analysed results were as follows:

Bony Results	***No. of patients***	***Percentage***
Excellent	10	50%
Good	6	30%
Fair	0	0%
Poor	4	20%



Functional Results	***No. of patients***	***Percentage***
Excellent	12	60%
Good	4	20%
Fair	3	15%
Poor	1	5%
Failure	0	0%



DISCUSSION

In our study, Transosseous Osteosynthesis by Ilizarov ring fixation system has proven to be effective in the management of infected nonunion of fracture Tibia. The mean follow up of this study is 7 months. The longest follow up is 17 months and the shortest about 5 months. This method helped us in the control of infection, to achieve solid bone union and to attain a good functional outcome. Most of the cases in our study had 2 operative procedures before they are submitted to the Ilizarov method, this is similar to the study conducted by RK Arora[66]. Male preponderance in this study is perhaps because of more outdoor activities of males. Our treatment protocol encouraged the patient to bear weight as early as tolerated, with the affected limb mostly within 48 hours after surgery. Early weight bearing with the affected limb as early as possible gives the patient self confidence and allows him to lead a near normal social life. Ilizarov ring fixator enabled us in the control of infection, to achieve bony union, to perform distraction osteogenesis in cases of bone loss. Toh & Jupiter[67] reported eradication of infection in 35 out of 37 cases of nonunion Tibia and Paley et al [68] in all of the 25 cases of nonunion Tibia.

Six of the patients with post operative edema were managed with elevation of the affected limb and anti-inflammatory drugs. During the course of the disease four patients had pin tract infection. They were managed either with pin removal and re-insertion or with topical antibiotics. Three patients had equinus deformity of the affected limb pre-operatively and two patients developed equinus deformity during the treatment period.

Hypotrophic regenerate was noticed at the corticotomy site during distraction period in two patients, for which periodical compression was given at the regenerate site. The regenerate consolidated well for one patient while the regenerate was hypotrophic for the other. Distraction every eight hours has been found to be as effective as the one done every six hours, in a similar series by Dubey et al[69].

One patient was noticed to have common peroneal nerve palsy post-operatively. He was managed with wire removal and re-insertion of the wire at the proximal most ring and a footdrop splint for the treatment period. Topical Zinc oxide cream and oral antibiotics were used to treat a patient who developed dermatitis of the affected leg.

One of the patient, 32 years female, discontinued the treatment and insisted on the removal of the apparatus. The apparatus was removed and a above knee slab was given to immobilise the fracture and the patient never turned for follow up.

At the end of the treatment two of the patients went on for fracture nonunion.

One patient had persistent infection at the fracture site. Accidentally he was diagnosed to have a renal tumor which left him immunocompromised and unable to overcome the infection.

The average time period for achievement for solid bone in our study is about 160 days.

In the study by Paley et al.,[70] , 25 cases of tibial non-union were treated with Ilizarov fixators which shows excellent bone results in 18 cases, good in 5 and fair in 2 based on union, persistent infection in 3 cases, deformity in 4 and limb shortening in 1 case. Functional results were excellent in 16 cases, good in 7, fair in 1 and poor in 1 based on return to daily activities, limp in 4 cases, equinus in 5 cases, dystrophy in 4 cases, pain in 4 cases and amputation for neurogenic pain in 1 case with bone loss.

In our study, 10 patients had excellent and 6 had good bony union. 12 patients had excellent and 4 patients had a good functional outcome according to the ASAMI scoring system. In general, eighty percent of the patients in our study had good to excellent bony and functional results according to the ASAMI scoring system.

The advantages of Ilizarov fixator proven in our study are as follows:

1. Reduced risk of bleeding, infection, and damage to the surrounding soft tissues.
2. No serious hampering of social and economic life due to walking with full weight bearing right after the operation.
3. Allows micromotion at the fracture site leading to good fracture union.
4. Improved vascularity, which leads to faster bone healing and good new bone formation during lengthening.
5. Preexisting deformities or deformities that occur during treatment can be corrected without the need for anesthesia.

The disadvantages of Ilizarov method in our study are

1. Bulky apparatus, cumbersome to some patients,
2. Time consuming procedure,
3. More labour-consuming compared to unilateral frames,
4. Multiple outpatient visits necessary,
5. Poor compliance with few patients,
6. Long learning curve.

CONCLUSION

The Ilizarov ring fixator gives an option of compression, distraction and bone transport, and is effective in the treatment of infected non-union of tibia where other types of treatment have failed . Ilizarov method is a minimally invasive, cheaper, versatile, cosmetic and 360 degree stable method. Early weight bearing is the key factor that distinguishes it from other conventional methods of fixationinfected non-union Tibia. It promotes early functional recovery, eliminating fracture disease.

1. It can be used in conditions with poor skin with adherent scars on the deformed bone,
2. This system allows early mobilisation and weight bearing during treatment period, decreases disuse osteoporosis and soft tissue atrophy.
3. The size of bone defect is not a limitation for reconstruction by distraction osteogenesis.

Weight bearing and the functioning of the joints while on the treatment is an advantage that cannot be matched by any other technique.

The prospective analysis in 20 cases of infected non union of fracture tibia managed with Ilizarov technique in our institution concludes that

1. Ilizarov technique has a definite role in the management of

    a. Infected nonunion with bone loss

    b. Infected nonunion with deformities

2. Reduces hospital stay

3. Provides full functional recovery

4. Allows early weight bearing

5. Gives definite union

6. Allows limb lengthening and deformity correction.

In the present scenario, the best available solution for management of infected nonunion of fracture Tibia associated with bone defects, limb length discrepancies, deformities is the Ilizarov ring fixation system. Transosseous osteosynthesis with Ilizarov ring fixation system is the safest, simplest, most economical and effective method for the management of infected nonunion fracture Tibia.

a) MASTER CHART

S. No.	Name	Age	Sex	Mode of injury	Type of fracture	Initial treatment	Side	Fracture site	Other Procedures	Status of infection	LLD	Acute shortening	Corticotomy	Bone transport	Bony result	Functional result
1	Sathish	27	M	RTA	Grade3B	Ext.Fixator	Right	M/3	Flap	Inactive	2cm	Yes	No	No	E	E
2	Gurusamy	35	M	RTA	Grade3B	Ext.Fixator	Left	M/3	None	Active	Nil	No	No	No	E	E
3	Selvam	28	M	RTA	Grade3B	Ext.Fixator	Left	M/3	Flap	Mild	2cm	Yes	No	No	E	E
4	Soundarajan	55	M	RTA	Closed	ILN	Right	Segmental	None	Active	Nil	No	No	No	E	E
5	Periyasamy	49	M	RTA	Closed	Plating	Right	P/3	Flap	Active	2cm	No	No	No	E	E
6	Perumal	45	M	RTA	Closed	ILN	Right	M/3	None	Active	Nil	No	No	No	E	E
7	Pandiyan	27	M	RTA	Grade3B	Ext.Fixator	Right	M/3	Flap	Active	2cm	Yes	No	No	E	E
8	Muniyappan	51	M	RTA	Grade3B	Ext.Fixator	Right	M/3	Flap	Active	Nil	No	Yes	Yes	E	E
9	Kandhasamy	65	M	RTA	Closed	Ext.Fixator	Right	Segmental	SSG	Active	1cm	No	No	No	E	E
10	Mohan	44	M	RTA	Grade3B	Ext.Fixator	Right	M/3	Flap	Active	1cm	Yes	Yes	No	E	E
11	Madhesh	31	M	RTA	Grade3B	Ext.Fixator	Right	D/3	Flap	Active	Nil	Yes	No	No	G	E
12	Arumugam	49	M	RTA	Grade3B	Ext.Fixator	Left	D/3	SSG	Active	2.5cm	Yes	Yes	No	G	E
13	Vijayakumar	38	M	RTA	Grade3B	Ext.Fixator	Left	D/3	None	Mild	2cm	No	Yes	Yes	G	G
14	Nehru	48	M	RTA	Grade3B	Ext.Fixator	Right	D/3	Flap	Inactive	2cm	Yes	Yes	No	G	G
15	Selvaraj	33	M	RTA	Closed	Conservative	Right	D/3	None	Inactive	Nil	No	No	No	G	G
16	Jagadeesan	46	M	RTA	Grade3B	Ext.Fixator	Right	D/3	SSG	Inactive	2cm	No	No	No	G	G
17	Moorthy	36	M	RTA	Grade3B	Ext.Fixator	Left	M/3	Flap	Active	Nil	No	Yes	Yes	P	F
18	Raja	31	M	RTA	Closed	ILN	Left	M/3	Flap	Active	Nil	No	Yes	Yes	P	F
19	Arunachalam	45	M	RTA	Closed	Plating	Right	P/3	None	Inactive	2cm	No	No	No	P	F
20	Chellammal	33	F	Acc fall	Closed	Native	Right	M/3	None	Active	Nil	No	No	No	P	P

E - Excellent ; G - Good; F - Fair; P - Poor; P/3 - Proximal 3rd; M/3 - Middle 3rd; D/3 - Distilled 3rd; M - Male; F - Female; RTA - Road Traffic Accident

b) Proforma

6. Name : Age : Sex : IP Number:
7. Mode of injury :
8. Type of fracture : Side of fracture : Site of fracture :
9. Initial treatment :
10. Present status of infection :
11. Limb length discrepancy :
12. Abnormal mobility :
13. Range of movements :
14. Level of activity :
15. Associated comorbidities :
16. General examination :
17. Clinical diagnosis :
18. Radiograph :
19. Blood investigations :
20. Diagnosis :
21. Plan of treatment :
22. Surgery :
23. Complications :
24. Post operative rehabilitation :
25. Condition on discharge :
26. Follow up :
27. 1st 3rd
28.
29. 2nd 4th

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